Spins in Few Hole Quantum Dots and Quantum Dot Readout in GaAs/AlGaAs Heterostructures

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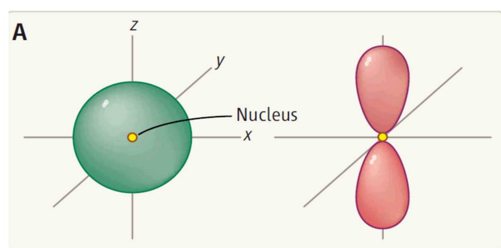
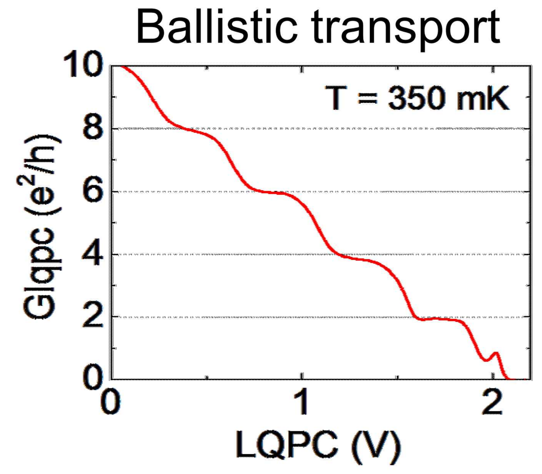
Hole Spins in Quantum Dots in GaAs

Advantages of hole spins in GaAs for qubits:

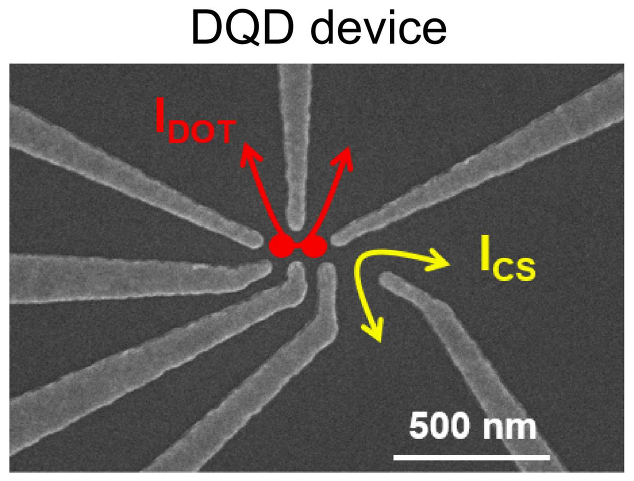
- Fast spin rotations using strong spin-orbit coupling
- Reduced hyperfine interaction compared to electrons
- No valley complications
- Direct bandgap and tunable g-factor for photon to spin transfer
- High mobilities and long mean free paths for nanostructures where transport is not impeded by defects



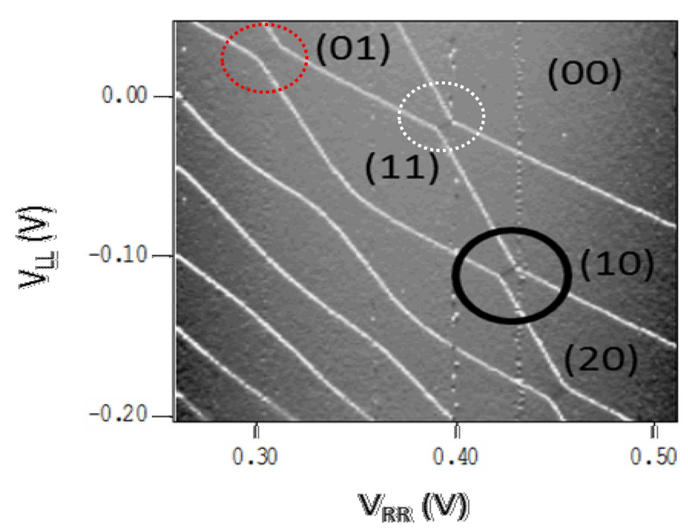
Ballistic transport



SEM of GaAs Hole DQD device

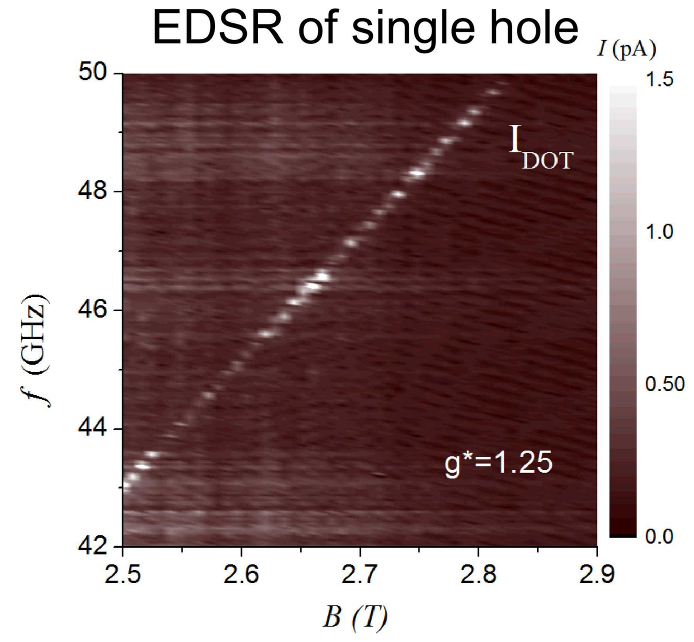


Few-hole regime in DQD

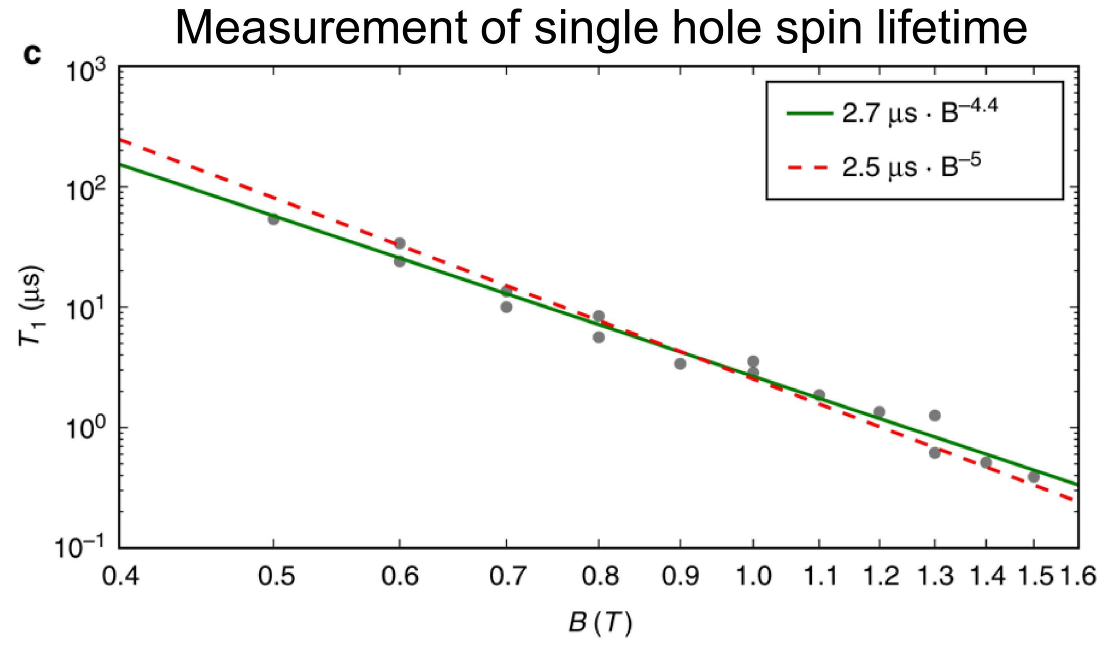


- P-type quantum dots fabricated at CINT allow for study of physics of single hole spins in quantum dots
- NRC group has characterized g-factor, spin-orbit interaction, spin-lifetime, and fast spin rotations (EDSR)
- Future plans to measure hole spin coherence time and investigate photon to spin transfer

EDSR of single hole



Measurement of single hole spin lifetime



User Project Publications:

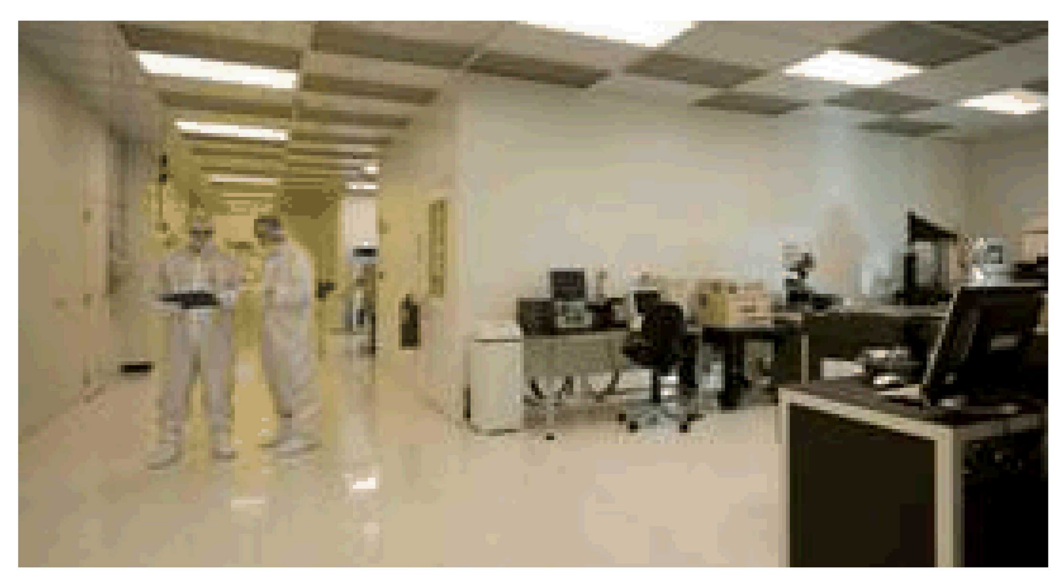
A. Bogan *et al.*, Phys. Rev. Lett. (2017)
A. Bogan *et al.*, Phys. Rev. Lett. (2018)
A. Bogan *et al.*, Comm. Phys. (2019)

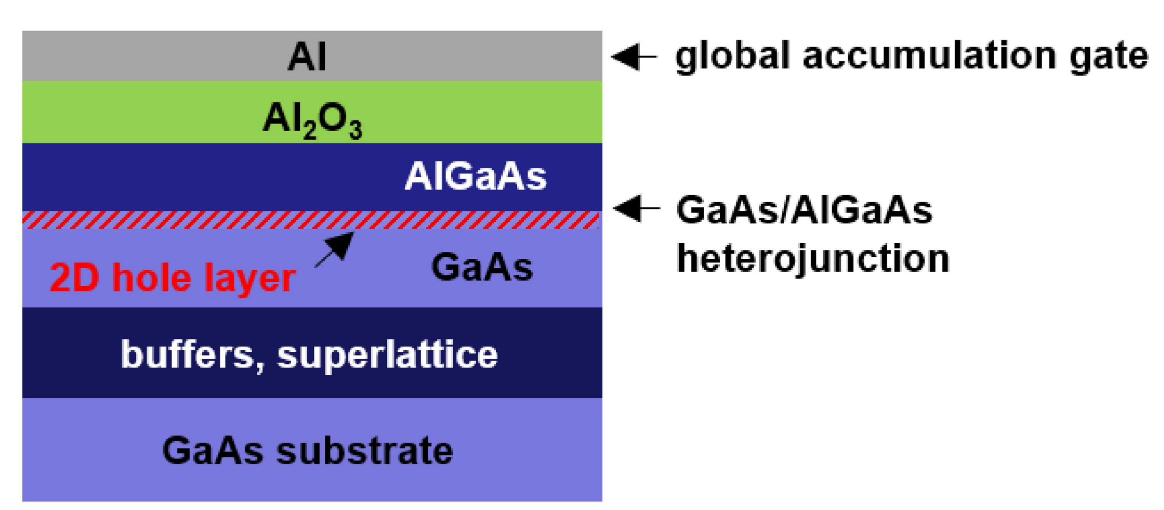
Key Facilities and Capabilities

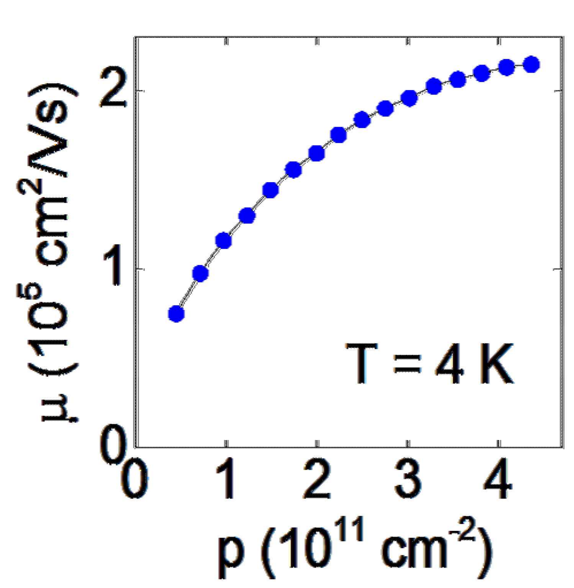
This work leverages CINT's unique, world-class capabilities in MBE growth of GaAs/AlGaAs heterostructures and nanofabrication facilities (Integration Lab)

MBE of high mobility III-V heterostructures (John Reno)

CINT Integration Lab (John Nogan)





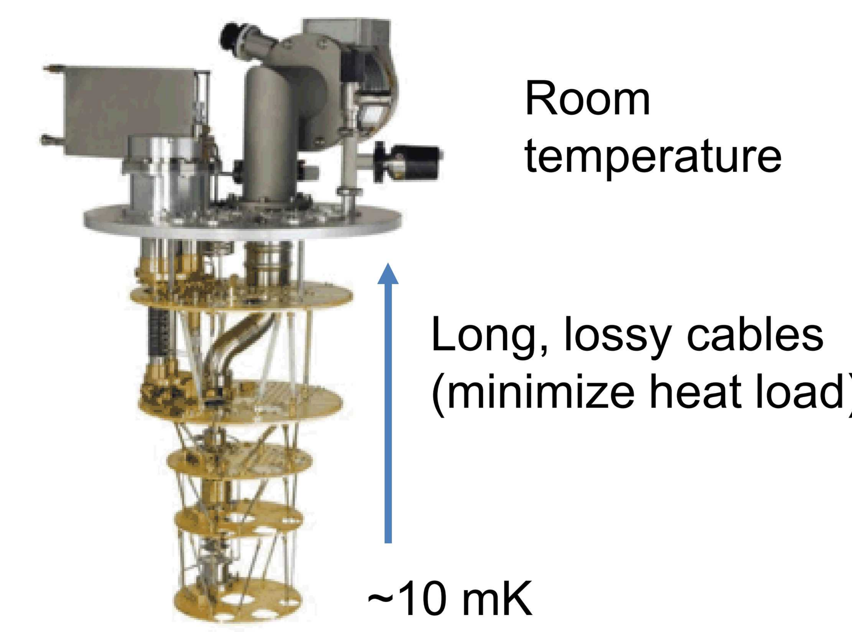


- High mobility p-type channels formed in CINT GaAs/AlGaAs heterostructures provide a platform for hole nanostructure devices
- Mobility > 1×10^5 cm^2/Vs, mean free path > 1 μm → ballistic transport in nanostructures

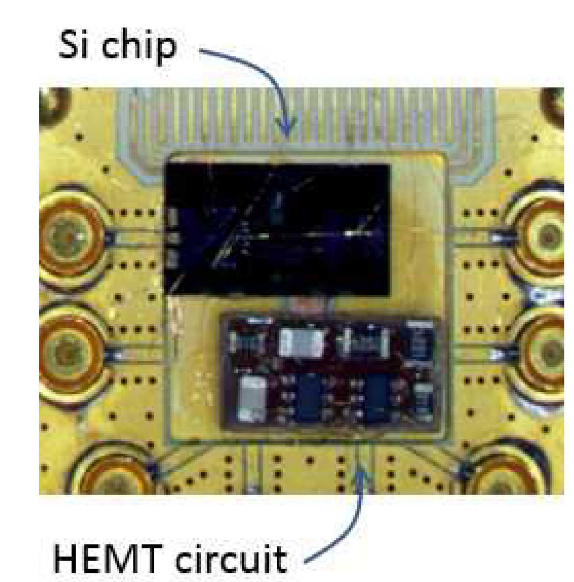
L.A. Tracy, T.W. Hargett, J.L. Reno, Appl. Phys. Lett. (2014).

Integrated HEMT Amplifiers for Quantum Dot Readout

Problem: Measurement of devices at milliKelvin temperatures is slow and has limited signal to noise ratio

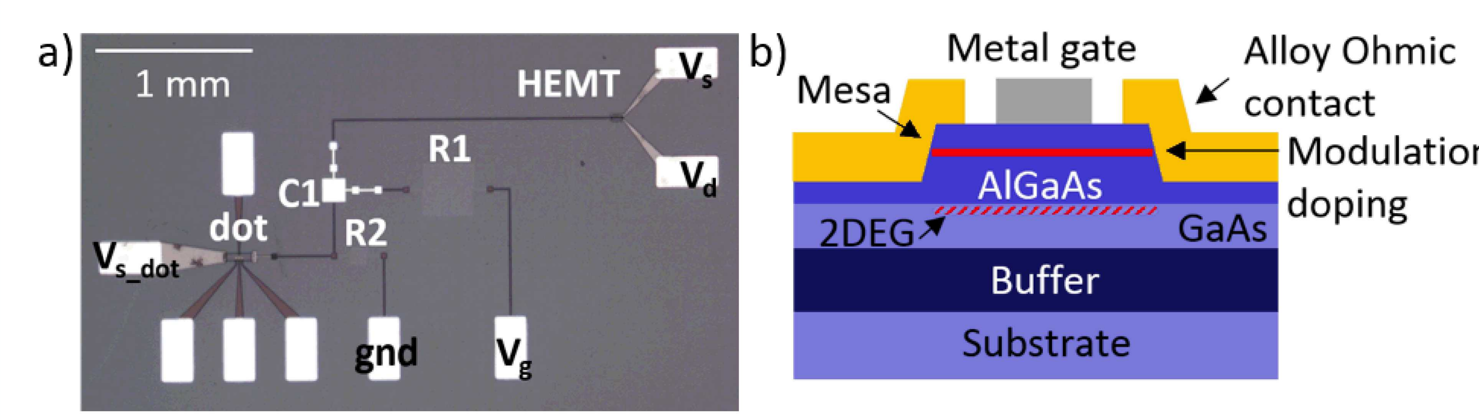


- Long cables impact room temperature preamp performance
- Allowable heat load at bottom stage few μW
- For qubits, desire fast readout for error correction



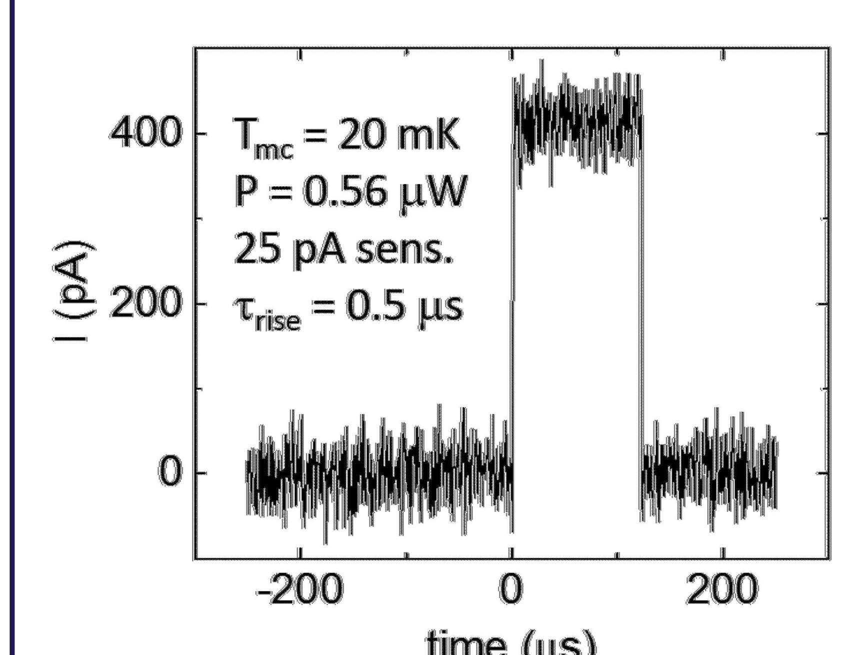
- Previous approach: amplification with commercial HEMT adjacent to quantum dot sample
- Can we improve performance with integration and custom high mobility GaAs/AlGaAs heterostructures?

Results: On-chip HEMT amplifier with quantum dot



GaAs chip with HEMT, passives, and quantum dot

Cross sectional diagram of HEMT



- Allows detection of charge tunneling event with 0.5 μs rise time.
- 20x lower power consumption compared to commercial HEMT circuit for similar performance
- Dot temperature ~300 mK (40 mK rise)

User Project Publications:

L.A. Tracy, J.L. Reno, S. Fallahi, M.J. Manfra, Appl. Phys. Lett. (2019).

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